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Influence of Extrusion Conditions on Techno-functional Properties, Phytochemical Contents and Antioxidant Activity of Rice-based Extrudates Containing Powder of Purslane (*Portulaca oleracea* L.) and Jew's Mallow (*Corchorus olitorius* L.) Leaves

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PURSLANE (*Portulaca oleracea* L.) and Jew's mallow (*Corchorus olitorius* L.) leaves have several desirable characteristics as functional ingredients for the production of healthy new foods. In this study, the influence of extrusion conditions including material type, feed moisture content and barrel temperature on techno-functional properties, phytochemical contents and antioxidant activity of rice-based extrudates containing purslane and Jew's mallow leaves powder was investigated. Inclusion of purslane and Jew's mallow leaves powder into the rice flour formula significantly affected the techno-functional, physical properties, phytochemicals and antioxidants activity of the resultant extrudates. Increasing feed moisture content resulted in extrudates with higher bulk density (BD) and breaking strength (BS) and lower phytochemicals content. Higher barrel temperature resulted in extrudates with higher techno-functional properties. Furthermore, statistical analyses revealed that the interactions between process variables were significant. Correlation relationships between techno-functional, physical properties, antioxidant activity and phytochemical contents were noticed. These results will be used to help define optimized process conditions for controlling and predicting qualities and characteristics of extruded products containing purslane and Jew's mallow leaves powder.

Keywords: Extrusion conditions,Techno-functional properties, Purslane, Jew's mallow.

Introduction

Due to the increasing awareness of the consumers about the importance of healthy diets, food manufactures are recently facing great challenges for developing new products with some health-enhancing features in terms of nutritional and functional values (Munekata et al., 2020). One of these products is the extruded snacks whose consumption substantially increased in the past three decades especially when produced from health-enhancing foods. Although the extruded snacks are perceivably considered by many consumers as unhealthy food items because they usually contain high calories and fat levels with low protein and fiber contents, extruded snacks can be also a good carrier of nutrients' supplementation if processed properly to fulfill the desire of the health-conscious consumers (Kaur et al., 2012). Thus, several research endeavors have been performed to enhance the nutritional quality of extruded snacks by using different food types such as corn, rice, wheat or potato flour (Morsy et al., 2015 and Singha et al., 2018a) or even by using some by-products such as those resulted during the processing of some fruits and vegetables (Korkerd et al., 2016 and Rayan et al., 2018).

As an inexpensive, high-temperature and short-time technology, the methods used in extrusion cooking; mixing, shearing and forming are extremely important in producing such convenience, attractive extruded snacks. When

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the extrudate ingredients are exposed over a short period to high temperature, shear stress and pressure, many chemical and structural transformations are occurred which affect the microstructure, chemical composition and/or the macroscopic structure of the final product. Due to their good characteristics especially the expansion properties, most commercially extruded snacks are recently prepared from grains such as rice, corn and wheat. For instance, rice as a widely grown cereal grain provides all essential features required for producing good extruded snacks, but its nutritional value is questionable for many consumers. Since rice is consumed extensively in many countries, it could be used as a fortification vehicle for overcoming micronutrient deficiencies (Muthayya et al., 2014). In this sense, some health beneficial ingredients such as beans, prickly-pear cactus, dried broccoli sprout, herbs, grain legumes, dates and tomato lycopene could be added to the extruded snacks made from rice to produce new high-nutritional value products (Bisharat et al., 2013; Dehghan-Shoar et al., 2010 and El-Samahy et al., 2007). Some other ingredients having nutritional and medicinal benefits such as purslane (*Portulaca oleracea*) are recently received great interests from researchers to fortify food products with ω-3 fatty acid, α-linolenic acid, antioxidants, flavonoids, crude protein, water-soluble polysaccharides (El Kashef et al., 2018; Gonnellaet al., 2010). Also, the fresh leaves and tender shoots of Jew's mallow (*Corchorus olitorius*) have been used efficiently in this kind of applications because they are nutritious, rich in beta-carotene, chlorophylls, phenolic compounds, minerals, protein, folate, vitamins, fatty acids (especially omega-3 fatty acids) and dietary fiber. Also, they have been proved to provide some health-related benefits due to its antioxidant properties, antitumor promotion, antibacterial activity, ability to reduce serum cholesterol in liver, managing diabetes and hypertension (Youssef et al., 2014). Moreover, the leaves of Jew's mallow were reported as good sources of phytochemicals and antioxidant activities (Morsy et al., 2015).

In fact, there are few studies were focused on enrichment of extruded snacks with herbs and vegetables not only to obtain new convenient products with acceptable quality but also for enhancing the nutritional and medicinal values of final products. Thus, this study aimed to (1) investigate the influence of ingredient type and extrusion conditions such as feed moisture and barrel temperature to produce new rice extrudates fortified with dried purslane and Jew's mallow leaves, (2) study the techno-functional properties, phytochemicals content and antioxidant activities of the resultant extruded snacks, and (3) explore the relationship between techno-functional features and the physical properties of the resultant extrudates.

Materials and Methods

Materials

Raw materials

Fresh harvested purslane (*Portulaca oleracea* L.) and Jew's mallow (*Corchorus olitorius* L.) were collected from private fields at Ismailia Governorate, Egypt. The green leaves of both plants were washed then drained and left on a cheesecloth to dry at room temperature (34±2°C) for 15 min. The drained leaves were freeze-dried for 36 hr at -70°C using a vertical freeze-drier (CPERON, FDU-7006, Gyeonggi, Korea). Dried leaves were milled and stored at 4°C until further uses. Rice grains was procured from the local market (Ismailia Governorate, Egypt), then milled with a laboratory mill to obtain homogenous particle size.

Chemicals and reagents

The Folin-Ciocalteu's reagent, sodium carbonate anhydrous (Na_2CO_3), gallic acid, aluminum chloride ($AlCl_3$, 6 H_2O) and sodium hydroxide (NaOH) were purchased from Fluka Company. Sodium nitrite ($NaNO_2$), quercetin, 2.2-diphenyl-1-picrylhydrazyl (DPPH), 6-hydroxy- 2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox), potassium persulfate and 2,2′-azino-bis (3-ethylbenzothiazoline–6-sulfonic acid) diammonium salt (ABTS) were purchased from Sigma-Aldrich CO. Methyl alcohol, hexane and acetone were purchased from Scharlab CO.

Methods

Sample preparation

Rice, purslane and Jew's mallow leaves powder were blended (in 1 kg lots) to obtain the desired ratios: control rice (100%), rice/ Purslane leaves powder (98/2%) and rice/ Jew's mallow leaves powder (98/2%). Three batches were prepared.

Extrusion cooking

The extrusion trials were conducted using a laboratory scale single-screw extruder (Barabender, 20 DN, Model No. 186501, type 832500) equipped with feeding device (AEV300, NO.141923, type GNF1014/2) with die rod type 3 mm. During extrusion; the feed composition, moisture content, and temperature varied. The raw mixtures were fed at a rate of 160 rpm (about 7.2 kg/ h), screw speed was 250 rpm. The ingredients were discharged into the extruder hopper when the extruder zones reached to the desired temperatures (100, 140, 140 and 100, 180, 180). After extrusion process, the resultant extrudates were collected, dried at 100^{o}C for 5 min, allowed to reach room temperature then stored at 4^{o}C in polyethylene sealed bags until analysis.

Determination of techno-functional properties of the resultant extrudates

Expansion ratio (ER)

The extrudate diameter was measured using a caliper (Mitutoyo Corp., Japan) according to the method of Chinnaswamy & Hanna (1988) (ten randomly pieces were chosen). ER was calculated as a ratio of extrudate diameter average to the die hole.

Bulk density (BD)

The bulk density of the extrudates was determined by the method described by Alvarez-Martinez et al. (1988). Ten randomly pieces were chosen.

Breaking strength (BS)

Breaking strength was determined according to the method described by Bourne (1981) using Barabender Struct-O-Graph (Model No.8603, OHG, Dusburg). For each sample, the peak height of the resulting recorded curves was taken as a measure of texture. Ten randomly pieces were chosen.

Water absorption (WAI) and solubility (WSI) indices

WAI was determined according to the centrifugation method of Anderson et al. (1970). WSI was calculated as the quantity of dry solids retrieved from the WAI test by evaporating the supernatant.

Oil absorption index (OAI)

OAI was determined according to the method of Liadakis et al. (1993).

Determination of color attributes of the resultant extrudates

The color of grinded extrudate samples was measured with a Minolta color reader CR-10 (Osaka, Japan) as lightness (*L**), redness (*a**) and yellowness (*b**). For each sample, five measurements were taken in average.

The whiteness index (WI) of extrudate samples was calculated according to Bolin & Huxsoll (1991).

Determination of pigments for the resultant extrudates

The β-carotene, chlorophyll *a* and *b* contents were carried out with the method of Barros et al. (2011). In brief, the grinded extrudate samples were extracted with acetone-hexane solvents mixture (4:6) then filtered. The obtained extract was adjusted to 10 ml with volumetric flask. Optical densities were recorded at wave lengths of 453, 505, 645 and 663 nm using a spectrophotometer (6505 UV/ VIS, Jenway LTD, Felsted, Dunmow, UK). The amounts of β-carotene, chlorophyll *a* and *b* were calculated and expressed as mg/100g dry weight.

Determination of phytochemicals content and antioxidant activity of the resultant extrudates

Extraction of total phenolic compounds**,** flavonoids and antioxidant activity was performed according to the method described by Barros et al. (2011). In brief, grinded extrudate samples were stirred with methanol on Orbital Shaker (LABLINE Instruments, Inc., USA) then filtered. The residue was then re-extracted with methanol. The methanol extracts were combined and stored at 4°C until analyses.

Determination of total phenolics content

Total phenolic compounds content was determined spectrophotometrically in the methanolic extracts, according to the Folin-Ciocalteu method with slight modifications (Barros et al., 2011). The extract was mixed with Folin–Ciocalteu phenol reagent then sodium carbonate (7.5%) was added. The tubes were agitated and kept at ambient temperature for color development. The optical densities values were recorded at 765 nm. A calibration curve using gallic acid was prepared and tested under the same conditions. TPC values were expressed as milligrams of gallic acid equivalents per 100 g dry weight.

Determination of total flavonoids content

Total flavonoids content was determined by the method described by Barros et al. (2011). Briefly, the extract was mixed with distilled water followed by addition of $NaNO_2$ (5%) solution. $AlCl_3$ solution (10%) was added and allowed to stand then NaOH solution (4%) was added. The optical density was recorded at 510 nm. A calibration curve using quercetin was prepared and TFC was determined from the linear regression equation of the calibration curve. TFC values were expressed as mg quercetin equivalents per 100 g dry weight.

Determination of DPPH radical-scavenging activity

The antioxidant activity was determined by DPPH method described by Morsy et al. (2015). The methanolic extract was mixed with DPPH solution. The optical density was recorded at 515 nm. The DPPH solution without extract was analyzed as a control. The antioxidant activity was expressed as DPPH radical–scavenging (%).

Trolox equivalent antioxidant capacity (TEAC)

The trolox equivalent antioxidant capacity (TEAC) was determined by the method of Morsy et al. (2015). In brief, after addition of sample extract or Trolox standard to the $ABTS^{\bullet+}$ solution, optical density was recorded at 734 nm. Ethanolic solutions of Trolox concentrations were used for calibration and TEAC was expressed as µmol Trolox per 100g dry sample.

Experimental design and statistical analysis

The experimental design comprising of three materials type (rice, purslane, Jew's mallow), two moisture content (16 and 20%) and two temperature treatments (140 and 180°C) as a 3×2×2 factorial design. A total of 12 treatments were conducted with three batches. Data were expressed as mean ± Standard Deviation (SD). The effect of independent variables (material type and extrusion conditions) on the studied characteristics of the resultant extrudate samples was analyzed by analysis of variance (ANOVA). Duncan's multiple range test was used to detect significant differences between samples. The significant differences were established at $p \leq 0.05$. The analyses were carried out using SPSS program (version 17.0 SPSS Inc). The correlation between obtained data was calculated by Pearson's correlation coefficients (r). The correlation was interpreted by: $r < 0.20$, negligible; r = 0.20-0.40, low; r = 0.40-0.60, moderate; r = 0.60-0.80, marked and $r > 0.80$, high (Dehghan-Shoar et al., 2010).

Results and Discussion

Effect of material type and extrusion conditions on techno-functional properties of the resultant extrudates

Expansion ratio (ER)

The ER of the resultant extrudate samples was found to be affected by the material type, feed moisture content and the extrusion temperature (Table 1). The ER was significantly reduced by increasing the feed moisture content for rice (100%), rice/ purslane (98/2%), rice/ Jaw's mallow extrudates. However, the expansion ratio was increased by increasing the barrel temperature. Oke et al. (2013) studied the effect of moisture content on radial size and expansion ratio, and concluded that increasing the moisture content of feeding materials decreased the drag force, thereby exerting less pressure at the die and resulting in lesser expansion of extrudates, which in turn reduced the radial size and expansion ratio of extrudates. The interactions between material type and extrusion conditions (feed moisture content and barrel temperature) were significant. Fletcher et al. (1985) studied the effects of rice flour levels on the expansion ratio of extrudates. The authors reported that increasing levels of rice flour would affect the degree of fill and time of residence, induce the amylopectin networks degradation, and change characteristics of melt rheology, resulting in greater impact on the elastic properties and alteration in product density and expansion. In addition, the decrease in expansion ratio may be due to the high content of fiber and protein from purslane and Jaw's mallow and their interaction, which competes for the free water in the matrix, reducing its capacity to expand (Rayan et al., 2018).

Bulk density (BD)

The BD of extrudates reflects the overall expansion, development of pores and changes in cell structure of the extrudates during processing. The effects of material type and extrusion conditions on the bulk density of the resultant extrudates are shown in Table 1. Replacing rice flour with purslane 2% led to a significant decrease ($P<0.05$) in bulk density of the resultant extrudates at all process variables. Similarly replacing rice flour with Jaw's mallow significantly decreased bulk density of resultant extrudates at 16% feed moisture and at both barrel temperature levels. However, increasing the moisture feed resulting a significant increase in bulk density of the resultant extrudates. In addition, increasing the barrel temperature resulted in a significant decrease in the density of resultant extrudates. Our results are in agreement with those obtained by Ding et al. (2005) who explored that increased feed moisture causes noticed increases in extrudate density at all studied temperatures. However, the increase in barrel temperature resulted in a slight decrease in the resultant extrudates density. A decrease in bulk density with increasing extrusion temperature was also noticed for blends of rice and chickpea flours during extrusion (Bhattacharya & Prakash, 1994). The degree of overheating of water increases as the extrusion temperature is increased which facilitates formation of bubbles that will result in a decrease in the melt viscosity leading to reduced density (Singha et al., 2018b). Feeding moisture content is the main factor that affects the density of extrudates and expansion. Increasing the feed moisture content during extrusion will alter the molecular structure of amylopectin, decrease the melt elasticity and the expansion but increase the density of extrudates (Fletcher et al., 1985 and Ding et al., 2005). The analysis of variance of process variables indicated that the bulk density of the resultant extrudates was found to be affected by the material type. However, the interaction between the feed moisture content and the extrusion temperature was insignificant.

Water absorption index (WAI) and water solubility index (WSI)

The effects of material type and extrusion conditions on WAI of extrudates are shown in Table 1. The extrusion conditions (feed moisture and barrel temperature) were found to have a significant effect on the WAI of the extrudates. Increasing the content of feed moisture significantly decreased the WAI of rice (100%) extrudates. However, WAI was significantly increased by the increase in feed moisture at higher barrel temperatures for rice/purslane (98/2%) and rice/Jaw's mallow (98/2%) extrudates. Kaushal et al.(2019) reported that feed moisture and extrusion temperatures had a strong impact on gelatinization during extrusion, thereby influencing the WAI. At higher temperature, starch granules are disrupted and more water is bounded resulting in increased WAI. Kumar et al.(2010) found that increasing the extrusion temperatures resulted in an increase in WAI of resultant estrudates which is in agreement with our current findings. The WAI has been found to increase with increasing in moisture content of feeding materials (Ding et al., 2005). The starch viscosity will be low at higher moisture content and the starch molecules will move freely thus enhancing the heat penetration as a result of increased gelatinization (Seth et al., 2015). Nonetheless, Sobukola et al. (2012) explained that the lower moisture content imparts more shearing stress in the barrel, resulting in more mechanical damage to starch, and thus low WAI. The combination effect between the material type, feed moisture content and barrel temperature was significant.

Water solubility index (WSI) determines the degree of starch dextrinization and degradation of molecular compounds during extrusion process. It reflects the level of soluble polysaccharide released from the starch component after extrusion. As seen in Table 1, increasing in feed moisture content and barrel temperature has been found to cause a significant increase in WSI of the resultant extrudates. These findings are similar to those reported for rice based extrudates by Ding et al. (2005). Sobukola et al. (2012) reported that the rise in barrel temperature resulted in an increase in WSI due to the increase in solubility of starch molecules.

Oil absorption index (OAI)

The ability of food protein to bind water and oil depends on the intrinsic factors such as composition of amino acids, protein conformation and hydrophobicity or surface polarity (Chandra and Samsher, 2013). The high OAC samples are better for retaining flavor. OAI of the extrudates increased significantly ($P \leq 0.05$) when purslane and Jaw's mallow leaves powder were incorporated (Table 1). The oil absorption index was highest in products processed at higher barrel temperature, but this decreased by increasing the feed moisture content. The increase in oil absorption could be attributed to the high of degradation starch in the extrudates due to the high input of thermal energy (Omohimi et al., 2014). The analysis of variance of process variables results indicated that oil absorption index of the resultant extrudates was found to be affected by the material type and extrusion conditions as the interactions between all variables were significant.

Breaking strength (BS)

As seen in Table 1 breaking strength was affected by the material type, feed moisture content that decreased with the inclusion of purslane and Jaw's mallow leaves powder except for Jaw's mallow at moisture content of 20%. There were a noticed increase in the BS by increasing the feed moisture content for both rice (100%) and rice/ Jaw's mallow (98/2%) extrudates. These results are in agreement with those reported by Gui et al. (2012) who discovered that the breaking strength of red ginseng extrudates increased as feed moisture content increased. The breaking strength depends on the strength of cell wall and the degree of expansion. It has been proposed that the reduction of melt viscosity would support bubble growth and provide a softer texture (Gui et al., 2012). Increased barrel temperature caused increased in breaking strength of the resultant extrudates. Analysis of variance results of process variables indicated that the interactions between the material type and extrusion conditions were insignificant.

TABLE 1. Effect of material type and extrusion conditions (feed moisture content and barrel temperature) on techno-functional properties of the resultant extrudates

Material type	Extrusion conditions		Techno-functional properties					
	Feed moisture (%)	Temperature (°C)	ER	BD (g/ ml)	WAI (g/ g)	WSI (%)	OAI	BS (BU)
Rice (100%)	16	140	$3.29^{a}\pm0.18$	$0.51^{d}\pm0.01$	$8.67^{b}\pm0.48$	$26.00^{e}\pm0.82$	$1.80^{f}\pm0.09$	$681^{abcd}\pm70$
		180	$3.28^{a}\pm0.30$	$0.53^{c}\pm0.00$	$9.04^{ab}\pm0.47$	$23.00^{e}\pm1.49$	$2.70^{c}\pm0.13$	$749^{abc}\pm33$
	20	140	$3.05^{abcd}\pm0.21$	$0.63^{a}\pm0.01$	$7.74^{cd}\pm0.14$	$18.50^{f}\pm0.47$	$1.40^{g}\pm0.07$	$887^{a}\pm62$
		180	$2.98^{bcd}\pm0.09$	$0.45^{f}\pm0.01$	$6.44^{e}\pm0.51$	$25.50^{e}\pm1.00$	$2.50^{d}\pm0.13$	$813^{ab}\pm62$
Rice/ purslane (98/ 2%)	16	140	$3.15^{abc}\pm0.19$	$0.49^{e}\pm0.01$	$7.89^{c}\pm0.07$	$34.40^{cd}\pm0.41$	$2.70^{c}\pm0.08$	$169^{f}\pm29$
		180	$3.24^{ab}\pm0.15$	$0.30^{j}\pm0.00$	$7.14^{d}\pm0.07$	$47.00^{a}\pm1.04$	$3.80^{a}\pm0.13$	$399^{cdef}\pm22$
	20	140	$2.62^{e}\pm0.08$	$0.45^{f}\pm0.01$	$7.80^{c}\pm0.12$	$35.00^{bcd}\pm1.15$	$2.70^{c}\pm0.12$	$248^{ef}\pm62$
		180	$2.93^{cd}\pm0.11$	$0.42^{g}\pm0.01$	$7.92^{c}\pm0.07$	$43.50^{a}\pm0.41$	$2.60^{cd}\pm0.12$	$369^{def}\pm8$
Rice/ Jew's mallow (98/ 2%)	16	140	$3.25^{ab}\pm0.13$	$0.41^{h}\pm0.01$	$9.59^{a}\pm0.47$	$37.50^{b}\pm0.41$	$3.00^{b}\pm0.08$	$523^{bcdef}\pm57$
		180	$3.23^{ab}\pm0.21$	$0.38^{i}\pm0.00$	$5.12^{f}\pm0.47$	$37.50^{b}\pm0.58$	$3.10^{b}\pm0.25$	$546^{abcde}\pm52$
	20	140	$2.81^{de}\pm0.10$	$0.57^{b}\pm0.01$	$7.52^{cd}\pm0.67$	$36.50^{bc}\pm1.00$	$2.10^{e}\pm0.08$	$748^{abc}\pm56$
		180	$3.24^{ab}\pm0.33$	$0.57^{b}\pm0.01$	$9.62^{a}\pm0.67$	$33.00^{cd}\pm0.67$	$2.50^{d}\pm0.13$	$789^{ab}\pm27$
Analyses of variance								
Main effects								
Material Type (M)			***	***	**	***	***	***
Feed moisture content (FM)			***	***	ns	**	***	**
Temperature (T)			***	***	***	***	***	ns
Interaction								
M*FM			*	***	***	ns	***	ns
M*T			**	***	***	***	***	ns
FM*T			**	ns	***	ns	***	ns
M*FM*T			*	***	***	***	***	ns
R^2			56.72	99.68	90.68	89.10	96.09	52.58
CV%			6.12	1.12	5.31	9.05	4.90	42.16

Values are means ± standard deviation. Means with different character in the same column are significantly different at $p < 0.05$. R^2:the coefficient of determination (evaluates how much of the variability in the actual values); CV: coefficient of variation (evaluates the relative closeness of the predictions to the actual values).
^{ns} not significant; * significant at $p < 0.05$; ** significant at $p < 0.01$; *** significant at $p < 0.001$.

Effect of material type and extrusion conditions on CIE color coordinates and WI values of the extrudates

Color is a predominant quality characteristic since it influences by the degree of chemical reactions and amount of cooking that occurs during extrusion. Color changes in extrudates are associated with degradation of pigments, the level of browning reactions, and the extrusion conditions. According to Kaushal et al. (2019), protein denaturation and Maillard reactions play major roles in color modifications during extrusion. As seen in Table 2 rice (100%) extrudates had higher lightness (*L**) and redness (*a**) values and lower Yellowness (*b**). Addition of purslane and Jaw's mallow significantly ($P < 0.05$) lowered the *L**and *a** values and increased *b** values of the resultant extrudates. The results also indicated that, *L**, *a** and *b** values decreased as feed moisture content and barrel temperature increased. It is well known that under high processing temperatures, reducing sugars and proteins in foods combine to induce Maillard reaction, which causes darkening of the final product (Kaushal et al., 2019). Analyses of variance result indicated that the CIE color coordinates were significantly affected by the material type, barrel temperature and feed moisture content. During the extrusion process, the color changes may result fromthe non-enzymatic browning and degradation of heat sensitive pigments (Gui et al., 2012).

The results also revealed that the whiteness index (WI) of rice (100%), rice/ purslane (98/2%) and rice/ jaw's mallow (98/2%) extrudates was significantly influenced by the material type and barrel temperature. Nevertheless, the effect of feed moisture content on WI was not significant. The highest WI was observed in rice (100%), whereas the lowest WI was observed in rice/ Jaw's mallow (98/2%) extrudates samples. This may be due to the biochemical changes occurring inside the extruder and changes in the ingredient's moisture content before processing. The interactions between the process variables; material type and extrusion conditions were significant.

Relationship between techno-functional and physical properties of the resultant extrudates

The extent of extrudates puffing can be determined from the values of ER and BD while exiting the die nozzle. The ER of extrudates shows the expansion in radical direction and perpendicular to extrudate flow, while BD is affected in all directions by the expansion (Falcone & Phillips, 1988). Density, fragility and texture of extrudates are influenced by the degree of expansion (Singha et al., 2018b). In our study, a negligible negative correlation (r = -0.122, $p<0.05$) was found between ER and BD (Table 3).

Several researchers have documented negative correlation between ER and BD during extrusion process (Singha et al., 2018b). Furthermore, a low positive correlation between ER and breaking strength (BS) (r = 0.219) and moderate positive correlation between BD and BS (r = 0.589). Rayas-Duarte et al. (1998) found a negative correlation relationship between the expansion index and the breaking strength of buckwheat flour mixes, which means that the decrease in breaking strength of extrudates was related with a high expansion index and low bulk density. Statistical analysis also, revealed that bulk density (BD) was negatively correlated with WSI (r = -0.738), OAI (r = -0.865) and *b** (yellowness) (r = -0.595) and positively correlated with *a** (redness) value (r = 0.503).

WSI was negatively correlated with WAI (r = -0.171). One possible reason is that the degraded starch and other polymers will interact to form high molecular weight compounds thus decreasing the WSI and increasing WAI. In other words, more gelatinization leads to less soluble solids. Furthermore, WSI was found to have a negative correlation with BD (r = -0.738), BS (r = -0.599), *L** (r = -0.566) and *a** (r = -0.747) and WI* (r = -0.745) and positive correlation with OAI (r = 0.739) and *b** value (r = 0.890). Oil absorption index (OAI) was negatively correlated with BD (r = -0.865), BS (r = -0.551) and *a** value (r = -0.733) and positively correlated with *b** value (r = 0.658). Breaking strength was negatively correlated with WSI (r = -0.599), OAI (r = -0.551), *b** (r = -0.776) and positively correlated with a* value (r = 0.558) and WI (r = 0.503).

Color parameters; *L** value (Lightness) was negatively correlated with WSI (r = -0.566) and *b** value (r = -0.679) and positively correlated with WI (r = 0.954). The *a** and *b** values had marked and high negative or positive correlations with techno-functional properties of the resultant extrudates as shown in Table 3. The WI values were negatively correlated with WSI (r = -0.745) and *b** (r = -0.866) and positively correlated with BS (r = 0.503), *L** (r = 0.954) and *a** (r = 0.591).

TABLE 2. Effect of material type and extrusion conditions (feed moisture content and barrel temperature) on CIE color coordinates and WI values of the resultant extrudates

Material type	Extrusion conditions		CIE color coordinates			WI
	Feed moisture (%)	Temperature (°C)	L^*	a^*	b^*	
Rice (100%)	16	140	$71.04^{cde}\pm2.65$	$3.82^{a}\pm0.85$	$13.36^{e}\pm1.57$	$67.80^{c}\pm2.22$
		180	$84.72^{a}\pm1.16$	$0.44^{c}\pm0.20$	$10.88^{f}\pm0.72$	$81.22^{a}\pm1.10$
	20	140	$75.32^{b}\pm1.52$	$1.36^{b}\pm0.24$	$10.52^{f}\pm1.16$	$73.12^{b}\pm1.60$
		180	$84.18^{a}\pm0.71$	$0.20^{c}\pm0.07$	$11.12^{f}\pm0.60$	$80.65^{a}\pm0.63$
Rice/ purslane (98/ 2%)	16	140	$70.70^{cde}\pm1.13$	$-2.16^{de}\pm0.38$	$25.28^{ab}\pm0.90$	$61.23^{e}\pm1.03$
		180	$72.70^{c}\pm0.81$	$-2.82^{e}\pm0.91$	$26.06^{a}\pm1.16$	$62.13^{de}\pm0.78$
	20	140	$71.48^{cd}\pm0.85$	$-1.94^{d}\pm0.66$	$22.66^{c}\pm0.96$	$63.50^{d}\pm0.66$
		180	$66.88^{fg}\pm1.58$	$-1.52^{d}\pm0.29$	$24.42^{abc}\pm2.04$	$58.80^{fg}\pm2.19$
Rice/ Jew's mallow (98/ 2%)	16	140	$68.82^{ef}\pm2.23$	$-1.88^{d}\pm0.55$	$23.44^{bc}\pm2.21$	$60.86^{ef}\pm1.69$
		180	$70.04^{cde}\pm1.10$	$-2.26^{de}\pm0.48$	$23.64^{bc}\pm0.75$	$61.76^{de}\pm1.07$
	20	140	$64.62^{gh}\pm0.60$	$-1.54^{d}\pm0.32$	$20.68^{d}\pm0.92$	$58.98^{fg}\pm0.52$
		180	$63.24^{h}\pm2.70$	$-1.74^{d}\pm0.59$	$20.72^{d}\pm0.76$	$57.73^{g}\pm2.10$
Analyses of variance						
Main effects						
Material Type (M)			***	***	***	***
Feed moisture content (FM)			***	***	***	ns
Temperature (T)			***	***	ns	***
Interaction						
M*FM			***	***	*	***
M*T			***	***	***	***
FM*T			***	***	**	***
M*FM*T			*	***	*	**
R^2			94.82	93.24	96.03	97.15
CV%			2.20	62.69	6.45	2.18

Values are means ± standard deviation. Means with different character in the same column are significantly different at $p < 0.05$. R^2:the coefficient of determination (evaluates how much of the variability in the actual values); CV: coefficient of variation (evaluates the relative closeness of the predictions to the actual values).
^{ns} not significant; * significant at $p < 0.05$; ** significant at $p < 0.01$; *** significant at $p < 0.001$.

TABLE 3. Correlation coefficients between techno-functional and physical properties of the resultant extrudates samples

	ER	BD	WAI	WSI	OAI	BS	L^*	a^*	b^*	WI
ER	1									
BD	-0.122	1								
WAI	0.233	0.392	1							
WSI	-0.108	-0.738	-0.171	1						
OAI	0.215	-0.865	-0.204	0.739	1					
BS	0.219	0.589	0.102	-0.599	-0.551	1				
L^*	0.114	-0.016	-0.181	-0.566	-0.004	0.272	1			
a^*	0.201	0.503	0.208	-0.747	-0.733	0.558	0.388	1		
b^*	-0.102	-0.595	-0.108	0.890	0.658	-0.776	-0.679	-0.830	1	
WI	0.108	0.235	-0.079	-0.745	-0.270	0.503	0.954	0.591	-0.866	1

Effect of material type and extrusion conditions on phytochemicals content of the extrudates

It was noticed that total phenolic compounds content of raw rice, rice/ purslane (98/ 2%) and rice/ Jaw's mallow (98/ 2%) was 31.66, 52.53 and 64.56 mg/100g dry weight, respectively (Table 4). Researchers have demonstrated that purslane and Jaw's mallow had higher phenolic content (Morsy et al., 2015 and El Kashef et al., 2018) thus it can be incorporated with rice flour to increase total phenolic content of extrudates. The phenolic compound content of raw rice, rice/ purslane and rice/ Jaw's mallow was significantly decreased after extrusion process ($p<0.05$). The obtained results are also consistent with previous studies carried out on bean-corn mixture extrudates (El Kashef et al., 2018). The highest decrease in phenolic compounds content was observed with increase of moisture feed content (20%). The results of analysis of variance revealed that TPC content was significantly affected by material type and feed moisture content. The interactions between the M*FM content and FM*T were significant. However, the interactions between M*T and M*FM*T were insignificant.

The content of total flavonoids of raw rice, rice/ purslane (98/ 2%) and rice/ Jaw's mallow (98/ 2%) was 30.95, 37.76 and 35.76 mg/100g dry weight, respectively. The flavonoids content of raw rice, rice/ purslane and rice/ Jaw's mallow was decreased significantly after extrusion process ($p<0.05$) (Table 4). Flavonoid compounds are heat sensitive and can destroy athigh temperature's exposure. Thus, losses in flavonoid content was expected to occur during the extrusion process, and break down of complex polyphenols into other phenolic or non-phenolic compounds, due to the high temperatures conditions (Xu and Chang, 2008). The analysis of variance results revealed that TFC content was significantly affected by the material type and temperature. The interactions between the M*T content and FM*T were significant. However, the interactions between M*FM and M*FM*T were insignificant.

Chlorophyll a, b and β-carotene were not determined in raw rice formulations (Table 4). The Chlorophyll a, b and β-carotene contents of rice/ purslane (98/ 2%) and rice/ Jaw's mallow (98/ 2%) extrudates were significantly decreased after extrusion cooking ($p<0.05$) when compared with the raw counterparts. The analyses of variance of results indicated that Chlorophyll a, b and β-carotene were significantly affected by the material type, feed moisture content and barrel temperature except for Chlorophyll b the impact of temperature was not significant. The interactions between the process variables (M*FM, M*T, FM*T and M*FM*T) were significant.

Effect of material type and extrusion conditions on antioxidant activity of the extrudates

Radical scavenging activity (DPPH, %) of raw rice flour, rice/ purslane (98/2%) and rice/ Jaw's mallow (98/2%) was 2.55, 6.15 and 8.15%, respectively. The inclusion of purslane and Jaw's mallow to rice flour significantly increased the antioxidant scavenging activity of the raw materials (p<*0.05*). The antioxidant scavenging activity of extruded rice flour showed an increase when compared with raw counterpart. However, the antioxidant scavenging activity of rice/ purslane (98/2%) and rice/ Jaw's mallow (98/2%) was decreased when compared with its raw formulations. The interactions effect of the process variables (M*FM, M*T, FM*T and M*FM*T) on the scavenging activity of resultant extrudates were insignificant (Table 5).

Trolox equivalent antioxidant capacity (TEAC) of raw rice flour, rice/ purslane (98/ 2%) and rice/ Jaw's mallow (98/ 2%) was 38.49, 114.10 and 115.15 µmol trolox equiv./ 100g, respectively (Table 5). The inclusion of purslane and Jaw's mallow to rice flour significantly increased the antioxidant capacity of the raw materials (p<0.05). Furthermore, rice extrudates showed an increase in antioxidant capacity when compared with its raw formulation. During extrusion cooking, when the barrel temperature was increased from 140°C to 180°C and feed moisture content was increased from 16% to 20%, antioxidant capacity was decreased but this decrease was not significant. Similarly, the interactions effect of the process variables (M*FM, M*T, FM*T and M*FM*T) on the TEAC antioxidant activity of the resultant extrudates were not significant. The antioxidant activity of the raw material formulations and extruded products might be attributed to the extrusion effect on (1) hydrolysis of complex polyphenols into simple polyphenols with scavenging activity, (2) interaction of the phenolic compounds with protein during heat treatment and (3) formation of Maillard reaction products (Rufian-Henares & Delgado-Andrade, 2009).

Relationship between antioxidant activity and phytochemicals content of the extrudates

Phenolic compounds and flavonoids are essential antioxidant components that deactivate free radicals by donating hydrogen atoms. They also possess ideal structural features to free radical scavenging (Aryal et al., 2019). Various literature studies showed a linear correlation relationship between total phenols, flavonoid contents and antioxidant activity (Shrestha and Dhillion, 2006). Through comparing the coefficients of correlation (r values), phenolic rings and flavonoid groups are proposed to be highly responsible for the plant extract's antioxidant activity. The statistical analyses indicated that radical scavenging activity of antioxidants (DPPH, %) showed high positive correlation (p<0.05) with TEAC antioxidant activity (r = 0.813), total phenolic compounds (TPC) (r = 0.697). TEAC was found to have a positive correlation with TPC, TFC, Chloro a, Chloro b and β-carotene (Table 6). TPC had also high positive correlation with total flavonoids content (TFC) (r = 0.917) and moderate correlation with Chloro a (r = 0.555), Chloro b (r = 0.646) and β-carotene (r = 0.750). TFC had a positive correlation with Chloro a (r = 0.717), Chloro b (r = 0.799) and β-carotene (r = 0.840).A high positive correlation relationship had found between Chloro a with Chloro b (r = 0.977) and β-carotene (r = 0.925). Similarly a strong positive correlation between Chloro b and β-carotene (r = 0.930) was observed.

Conclusion

Purslane and Jew's mallow leaves have several desirable characteristics as functional ingredients for the production of healthy new foods. The extrusion process led to further modifications such as improvements in the techno-functional, physical properties, phytochemicals and antioxidants activity. All the dependent variables could be controlled by appropriated processing conditions. Increasing feed moisture and barrel temperature significantly influenced the techno-functional, physicochemical properties, phytochemicals content and antioxidants activity. Furthermore, the interaction between the process variables was significant. Data from this extrusion study may be useful in predicting the expected performance of extruded materials. Furthermore, providing the potential use of rice flour mixed with purslane and Jew's mallow leaves powder to improvethe nutritional quality of final extruded products.

TABLE 4. Effect of material type and extrusion conditions (feed moisture content and barrel temperature) on phytochemicals content of raw and extruded samples

Material type	Extrusion conditions		Phytochemical content (mg/ 100g dry weight basis)									
	Feed moisture (%)	Temperature (°C)	TPC		TFC		Chloro a		Chloro b		β-carotene	
			Raw	Extruded	Raw	Extruded	Raw	Extruded	Raw	Extruded	Raw	Extruded
Rice (100%)	16	140	31.66^{c}_{A}	7.77^{d}_{B}	30.95^{b}_{A}	7.54^{bc}_{B}	ND	ND	ND	ND	ND	ND
		180		9.10^{d}_{B}		7.24^{bc}_{B}		ND		ND		ND
	20	140		8.22^{d}_{B}		7.84^{bc}_{B}		ND		ND		ND
		180		9.90^{d}_{B}		7.05^{c}_{B}		ND		ND		ND
Rice/ purslane (98/ 2%)	16	140	52.53^{b}_{A}	11.71^{bcd}_{B}	37.76^{a}_{A}	7.49^{bc}_{B}	35.62^{a}_{A}	7.22^{c}_{B}	12.29^{a}_{A}	0.40^{e}_{B}	7.46^{a}_{A}	0.80^{bc}_{B}
		180		13.92^{abc}_{B}		12.23^{a}_{B}		12.54^{a}_{B}		1.44^{a}_{B}		1.88^{a}_{B}
	20	140		11.01^{bcd}_{B}		7.58^{bc}_{B}		9.97^{b}_{B}		0.98^{bc}_{B}		1.18^{b}_{B}
		180		10.30^{bcd}_{B}		9.83^{abc}_{B}		5.72^{d}_{B}		0.69^{d}_{B}		0.98^{b}_{B}
Rice/ Jew's mallow (98/ 2%)	16	140	64.58^{a}_{A}	14.91^{ab}_{B}	35.46^{a}_{A}	8.80^{abc}_{B}	11.24^{b}_{A}	4.61^{e}_{B}	3.84^{b}_{A}	1.18^{ab}_{B}	4.01^{b}_{A}	0.96^{b}_{B}
		180		16.44^{a}_{B}		10.62^{ab}_{B}		7.33^{c}_{B}		1.20^{ab}_{B}		2.06^{a}_{B}
	20	140		11.56^{bcd}_{B}		10.61^{ab}_{B}		2.92^{f}_{B}		0.79^{cd}_{B}		0.40^{c}_{B}
		180		9.47^{cd}_{B}		9.05^{abc}_{B}		4.16^{e}_{B}		0.24^{e}_{B}		1.99^{a}_{B}
Analyses of variance												
Main effects												
Material Type (M)			***	***	**	***	***	***	***	***	***	***
Feed moisture content (FM)				***		ns		***		***		***
Temperature (T)				ns		*		***		ns		***
Interaction												
M*FM				**		ns		***		***		*
M*T				ns		**		***		***		***
FM*T				*		*		***		***		**
M*FM*T				ns		ns		***		***		***
R^2			79.52	90.80	45.13	86.67	93.26	99.94	89.62	99.33	63.00	99.28
CV%			14.88	10.36	9.60	10.06	14.95	3.00	19.06	10.36	24.65	10.84

Values are means of triplicates. Means with different small character in the same column or capital character between two column for each property are significantly different at $p < 0.05$.

R^2:the coefficient of determination (evaluates how much of the variability in the actual values); CV: coefficient of variation (evaluates the relative closeness of the predictions to the actual values).

[ns] not significant; [*] significant at $p < 0.05$; [**] significant at $p < 0.01$; [***] significant at $p < 0.001$.

TABLE 5. Effect of material type and extrusion conditions (feed moisture content and barrel temperature) on antioxidant activity of raw and extruded samples

Material type	Extrusion conditions		Antioxidant activity			
	Feed moisture (%)	Temperature (°C)	DPPH-radical scavenging activity (%)		TEAC (µmol trolox equiv./ g dry sample)	
			Raw	Extruded	Raw	Extruded
Rice (100%)	16	140	2.55^{c}_{B} ±0.86	4.33^{a}_{A}±0.39	38.49^{b}_{B} ±3.35	65.05^{a}_{A}±6.50
		180		3.68^{a}_{A}±0.88		55.20^{a}_{A}±1.90
	20	140		4.63^{a}_{A}±0.20		66.70^{a}_{A}±1.93
		180		3.65^{a}_{A}±0.20		66.70^{a}_{A}±5.78
Rice/ purslane (98/ 2%)	16	140	6.15^{b}_{A} ±0.81	4.85^{a}_{B}±0.59	114.10^{a}_{A} ±4.1	80.69^{a}_{B}±5.21
		180		3.88^{a}_{B}±0.59		87.13^{a}_{B}±3.79
	20	140		5.61^{a}_{B}±0.00		80.32^{a}_{B}±5.78
		180		3.92^{a}_{B}±0.98		66.63^{a}_{B}±5.77
Rice/ Jew's mallow (98/ 2%)	16	140	8.15^{a}_{A} ±1.18	5.83^{a}_{B}±0.59	115.15^{a}_{A} ±5.48	83.56^{a}_{B}±6.44
		180		5.07^{a}_{B}±0.29		79.61^{a}_{B}±5.72
	20	140		4.13^{a}_{B}±0.69		74.79^{a}_{B}±8.99
		180		4.20^{a}_{B}±0.40		62.55^{a}_{B}±0.00
Analyses of variance						
Main effects						
Material Type (M)			***	ns	***	*
Feed moisture content (FM)				ns		ns
Temperature (T)				*		ns
Interaction						
M*FM				ns		ns
M*T				ns		ns
FM*T				ns		ns
M*FM*T				ns		ns
R^2			76.51	58.10	97.38	63.67
CV%			24.44	18.70	7.05	21.72

Values are means ± standard deviation. Means with different small character in the same column or capital character between two column for each property are significantly different at $p < 0.05$.
.(R^2:the coefficient of determination (evaluates how much of the variability in the actual values); CV: coefficient of variation (evaluates the relative closeness of the predictions to the actual values
[ns] not significant; [*] significant at $p < 0.05$; [**] significant at $p < 0.01$; [***] significant at $p < 0.001$.

TABLE 6. Correlation coefficients between antioxidant activity and phytochemicals content of the studied samples.

	DPPH	TEAC	TPC	TFC	Chloro a	Chloro b	β-carotene
DPPH	1						
TEAC	0.813	1					
TPC	0.697	0.607	1				
TFC	0.411	0.400	0.917	1			
Chloro a	0.255	0.624	0.555	0.717	1		
Chloro b	0.353	0.651	0.646	0.799	0.977	1	
β-carotene	0.480	0.693	0.750	0.840	0.925	0.930	1

References

Alvarez-Martinez, L., Kondury. K. P. and Harper, J. M. (1988) A general model for expansion of extruded products. *Journal of Food Science*, **53**, 609–615. https://doi.org/10.1111/j.1365-2621.1988.tb07768.x

Anderson, R. A., Conway, H. F. and Peplinski, A. J. (1970) Gelatinization of corn grits by roll cooking, extrusion cooking and steaming. *Starch/ Stärke*, **22**, 130–135. https://doi.org/10.1002/star.19700220408

Aryal, S. Baniya, M. K., Danekhu, K., Kunwar, P., Gurung, R. and Koirala, N. (2019) Total phenolic content, flavonoid content and antioxidant potential of wild vegetables from western Nepal. *Plants*; 11, 8:96.doi:10.3390/plants8040096

Barros, L., Cabrita, L., Boas, M. V., Carvalho, A. M. and Ferreira, I. C. F. R. (2011) Chemical, biochemical and electrochemical assays to evaluate phytochemicals and antioxidant activity of wild plants. *Food Chemistry*, **127**, 1600–1608. https://doi.org/10.1016/j.foodchem.2011.02.024

Bourne, M. C. (1981) Food Texture and Viscosity:Concept and measurement.1st edition. Geneva, New York, USA by Academic Press, Inc.

Bhattacharya, S. and Prakash, M. (1994) Extrusion of blends of rice and chick pea flours: A response surface analysis. *Journal of Food Engineering*, **21**, 315–330. https://doi.org/10.1016/0260-8774(94)90076-0

Bisharat, G. I., Oikonomopoulou, V. P., Panagiotou, N. M., Krokida, M. K. and Maroulis, Z. B. (2013) Effect of extrusion conditions on the structural properties of corn extrudates enriched with dehydrated vegetables. *Food Research International*, **53**, 1–14. https://doi.org/10.1016/j.foodres.2013.03.043

Bolin, H. R. and Huxsoll, C. C. (1991) Control of minimally processed carrot (*Daucus carotes*) surface discoloration caused by abrasion peeling. *Journal of Food Science*, **55**, 415–424. https://doi.org/10.1111/j.1365-2621.1991.tb05293.x

Chandra, S. and Samsher (2013) Assessment of functional properties of different flours. African *Journal of Agricultural Research*, **8**, 4849–4852. DOI:10.5897/AJAR2013.6905

Chinnaswamy, R. and Hanna, M. A. (1988) Expansion, color and shear strength properties of corn starches extrusion-cooking with urea and salt. *Starch/Starke,* **40**, 186–190. https://doi.org/10.1002/star.19880400507

Dehghan-Shoar, Z., Hardacre, A. K. and Brennan, C. S. (2010) The physico-chemical characteristics of extruded snacks enriched with tomato lycopene. *Food Chemistry*, **123**, 1117–1122. https://doi.org/10.1016/j.foodchem.2010.05.071

Ding, Q., Ainsworth, P., Tucker, G. and Marson, H. (2005) The effect of extrusion conditions on the physicochemical properties and sensory characteristics of rice-based expanded snacks. *Journal of Food Engineering*, **66**, 283–289.https://doi.org/10.1016/j.jfoodeng.2004.03.019

El Kashef, R. K. H., Soliman, A. S., Hassan, H. M. M. and Abd- Elhak, N. A. (2018) Evaluation of total phenolic content and antioxidant activity of different solvent extracts of Egyptian purslane leaves. *Current Science International*, **7**, 616–623.

El-Samahy, S. K., El-Hady, E. A., Habiba, R. A. and Moussa-Ayoub, T. E. (2007) Some functional, chemical, and sensory characteristics of cactus pear rice-based extrudates. *Journal of the Professional Association for Cactus Development*, **9**, 136–147.

Fletcher, S. I., Richmond, P. and Smith, A. C. (1985) An experimental study of twin-screw extrusion cooking of maize grits. *Journal of Food Engineering*, **4**, 291–312. https://doi.org/10.1016/0260-8774(85)90009-3

Falcone, R. G. and Phillips, R. D. (1988) Effects of feed composition, feed moisture, and barrel temperature on the physical and rheological properties of snack-like products prepared from cowpea and sorghum flours by extrusion. *Journal of Food Science*, **53**, 1464–1469.https://doi.org/10.1111/j.1365-2621.1988.tb09300.x

Gonnella, M., Charfeddine, M., Conversa, G. and Santamaria, P. (2010) Purslane: a review of its potential for health and agricultural aspects. *European Journal of Plant Science and Biotechnology*, **4**, 131–136.

Gui, Y., Gil, S. K. and Ryu, G. H. (2012) Effects of Extrusion Conditions on the Physicochemical Properties of Extruded Red Ginseng. *Preventive Nutrition and Food Science,* **17**, 203–209. doi: 10.3746/pnf.2012.17.3.203

Kaur, G., Sharma, S., Nagi, H. P. S. and Dar, B. N. (2012) Functional properties of pasta enriched with variable cereal brans. *Journal of Food Science and Technology*, **49**, 467–474.doi: 10.1007/s13197-011-0294-3

Kaushal, P., Sharma, H. K. and Singh, A. P. (2019) Effect of extrusion processing on microstructural, physical, functional, antioxidant and textural properties of jackfruit flesh flour, rice flour and pigeon pea flour based extrudates. *International Food Research Journal,* **26**, 1045–1058.

Korkerd, S., Wanlapa, S., Puttanlek, C., Uttapap, D. and Rungsardthong, V. (2016) Expansion and functional properties of extruded snacks enriched with nutrition sources from food processing by-products. *Journal of Food Science and Technology,* 53, 561–570. doi: 10.1007/s13197-015-2039-1

Kumar, N., Sarkar, B. C. and Sharma, H. K. (2010) Development and characterization of extruded product of carrot pomace, rice flour and pulse powder. *African Journal of Food Science*, **4**, 703–717

Liadakis, G. N., Floridis, A., Tzia, C. and Oreopoulou, V. (1993) Protein isolates with reduced gossypol content from screw-pressed cottonseed meal. *Journal of Agriculture and Food Chemistry*, **41**, 918–922. https://doi.org/10.1021/jf00030a016

Morsy, N. E., Rayan, A. M. and Youssef K. M. (2015) Physico chemical properties, antioxidant activity, phytochemicals and sensory evaluation of rice-based extrudates containing dried Corchorus olitorius l. Leaves. *Journal of Food Processing and Technology,* **6**, 408. doi:10.4172/2157-7110.1000408

Munekata, P. E. S., Pateiro, M., Barba, F. J., Dominguéz, R., Gagaoua, M. and Lorenzo, J. M. (2020) Development of new food and pharmaceutical products: Nutraceuticals and food additives. *Advances in Food and Nutrition Research,* **92**,53–96. doi: 10.1016/bs.afnr.2019.12.001

Muthayya, S., Sugimoto, J. D., Montgomery, S. and Maberly, G. F. (2014) An overview of global rice production, supply, trade, and consumption. *Annals of the New York Academy of Sciences,* **1324**, 7–14. doi: 10.1111/nyas.12540

Oke, M. O., Awonorin, S. O., Sanni, L. O., Asiedu, R. and Aiyedun, P. O. (2013) Effect of extrusion variables on extrudates properties of water yam flour – a response surface analysis. *Journal of Food Processing and Preservation,* **37**, 456–473. https://doi.org/10.1111/j.1745-4549.2011.00661.x

Omohimi, C. I., Sobukola, O. P., Sarafadeen, K. O. and Sanni, L. O. (2014) Effect of Thermo-extrusion Process Parameters on Selected Quality Attributes of Meat Analogue from Mucuna Bean Seed Flour. *Nigerian Food Journal*, **32**, 21-30.https://doi.org/10.1016/S0189-7241(15)30092-8

Rayan, A. M., Morsy, N. E. and Youssef, K. M. (2018) Enrichment of rice-based extrudates with Cactus Opuntia dillenii seed powder: A novel source of fiber and antioxidants. *Journal of Food Science and Technology,* **55**, 523–531. doi: 10.1007/s13197-017-2961-5

Rayas-Duarte, P., Majewska, K. and Doetkott, C. (1998) Effect of the extrusion process parameters on the quality of buckwheat flour mixes. *Cereal Chemistry*, **75**, 338–345.doi: 10.1094/cchem.1998.75.3.338

Rufian-Henares, J. A., and Delgado-Andrade, C. (2009) Effect of digestive process on Maillard reaction indexes and antioxidant properties of breakfast cereals. *Food Research International*, **42**, 394–400. https://doi.org/10.1016/j.foodres.2009.01.011

Seth, D., Badwaik, L. S. and Ganapathy, V. (2015) Effect of feed composition, moisture content and extrusion temperature on extrudate characteristics of yam-corn-rice based snack food. *Journal of Food Science and Technology*, **52**, 1830–1838.doi: 10.1007/s13197-013-1181-x

Shrestha, P. M. and Dhillion, S. S. (2006) Diversity and traditional knowledge concerning wild food species in a locally managed forest in Nepal. *Agroforestry Systems*, **66**, 55–63.https://doi.org/10.1007/s10457-005-6642-4

Singha, P., Muthukumarappan, K. and Krishnan, P. (2018a) Influence of processing conditions on apparent viscosity and system parameters during extrusion of distiller's dried grains-based snacks. *Food Science and Nutrition*, **6**, 101–110. doi: 10.1002/fsn3.534

Singha, P., Singh, S. K., Muthukumarappan, K. and Krishnan, P. (2018b) Physicochemical and nutritional properties of extrudates from food grade distiller's dried grains, garbanzo flour, and corn grits. *Food Science and Nutrition*, **6**, 1914–1926. doi: 10.1002/fsn3.769

Sobukola, O. P., Babajide, J. M. and Ogunsade, O. (2012) Effect of brewer spent grain addition and extrusion parameters on some properties of extruded yam starch-based pasta. *Journal of Food Processing and preservation,* **37**, 734–743. https://doi.org/10.1111/j.1745-4549.2012.00711.x

Xu, B. and Chang, S. (2008) Total phenolics, phenolic acids, is flavones, anthocyanins and antioxidant properties of yellow and black soybeans as affected by thermal processing. Journal of Agriculture and Food Chemistry, **56**, 7165–7175. doi: 10.1021/jf8012234

Youssef, Kh. M., Mokhtar, S. M. and Morsy, N. E. (2014) Effect of hot air drying variables on phytochemicals and antioxidant capacity of Jew's mallow (*Corchorus olitorius* L.) leaves. *Journal of Food Science; Suez Canal University*, **2**, 1–8. doi: 10.21608/SCUJ.2014.6667

تأثير ظروف البثق الحراري على الخصائص التكنو وظيفية، محتوي المواد الفعالة والنشاط المضاد للأكسدة لمبثوقات الأرز المحتوية علي مسحوق أوراق الرجلة والملوخية

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[2] قسم الصناعات الغذائية (فرع الإقتصاد المنزلي) - كلية الزراعة - جامعة قناة السويس - الاسماعيلية - مصر

تحتوي أوراق الرجلة والملوخية علي العديد من الخصائص المرغوبة كمكونات وظيفية لإنتاج أغذية صحية جديدة. تم دراسة تأثير ظروف البثق الحراري (نوع المادة الخام، محتوي رطوبة المخلوط ودرجة حرارة البثق)على الخصائص التكنو وظيفية، محتوي المواد الفعالة والنشاط المضاد للأكسدة لمبثوقات الأرز المحتوية على مسحوق أوراق الرجلة والملوخية. أثرت إضافة مسحوق أوراق الرجلة والملوخية الي دقيق الأرز بشكل معنوي على الخصائص التكنو وظيفية، الطبيعية، محتوي المواد الفعالة والنشاط المضاد للأكسدة للمبثوقات الناتجة. أدي زيادة محتوي رطوبة المخلوط الي ارتفاع قيم الكثافة وقوة الكسر للمبثوقات الناتجة وانخفاض محتوي المواد الفعالة. أدي ارتفاع درجة حرارة البثق الي انتاج مبثوقات ذات خصائص تكنو وظيفية مرتفعة. علاوة على ذلك، أظهرت نتائج التحليل الاحصائي ان الارتباط بين متغيرات الدراسة كان معنويا. كما لوحظ وجود علاقات ارتباط بين الخصائص التكنو وظيفية والخصائص الطبيعية وكذلك بين محتوي المواد الفعالة والنشاط المضاد للأكسدة. النتائج المتحصل عليها تساعد في تحديد ظروف تصنيع مثلي وكذلك التحكم والتنبؤ بصفات وخصائص المنتجات المبثوقة التي تحتوي على مسحوق أوراق الرجلة والملوخية.